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ANDERSON ENGINEERING INC SPRINGFIELD MO  
NATIONAL DAM SAFETY PROGRAM, ARROWHEAD LAKES LOWER DAM (MO 302--ETC(U)  
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ARROWHEAD LAKES LOWER DAM  
DENT COUNTY, MISSOURI  
MO 38267

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**PHASE 1 INSPECTION REPORT  
NATIONAL DAM SAFETY PROGRAM**



United States Army  
Corps of Engineers  
Serving the Army  
Serving the Nation

**St. Louis District**

PREPARED BY: U.S. ARMY ENGINEER DISTRICT, ST. LOUIS

FOR: STATE OF MISSOURI



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## UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This report was prepared under the National Program of Inspection of Non-Federal Dams. This report assesses the general condition of the dam with respect to safety, based on available data and on visual inspection, to determine if the dam poses hazards to human life or property.		



DEPARTMENT OF THE ARMY  
ST. LOUIS DISTRICT, CORPS OF ENGINEERS  
210 NORTH 12TH STREET  
ST. LOUIS, MISSOURI 63101

IN REPLY REFER TO

SUBJECT: Arrowhead Lakes Lower Dam Phase I Inspection Report

This report presents the results of field inspection and evaluation of the Arrowhead Lakes Lower dam:

It was prepared under the National Program of Inspection of Non-Federal Dams

This dam has been classified as unsafe, non-emergency by the St. Louis District as a result of the application of the following criteria:

- 1) Spillway will not pass 50 percent of the Probable Maximum Flood
- 2) Overtopping could result in dam failure
- 3) Dam failure significantly increases the hazard to loss of life downstream

SIGNED

28 MAR 1980

SUBMITTED BY:

Chief, Engineering Division

Date

APPROVED BY:

SIGNED

28 MAR 1980

Colonel, CE, District Engineer

Date

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ARROWHEAD LAKES LOWER DAM  
DENT COUNTY, MISSOURI  
MISSOURI INVENTORY NO. 30267

PHASE I INSPECTION REPORT  
NATIONAL DAM SAFETY PROGRAM

Prepared By  
Anderson Engineering, Inc., Springfield, Missouri  
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Under Direction Of  
St. Louis District, Corps of Engineers

For  
Governor of Missouri

February 1980

PHASE I REPORT  
NATIONAL DAM SAFETY PROGRAM

Name of Dam: Arrowhead Lakes Lower Dam  
State Located: Missouri  
County Located: Dent  
Stream: Unnamed Tributary of Meramec River  
Date of Inspection: August 15, 1979

Arrowhead Lakes Lower Dam was inspected by an interdisciplinary team of engineers from Anderson Engineering, Inc. of Springfield, Missouri and Hanson Engineers, Inc. of Springfield, Illinois. The purpose of the inspection was to make an assessment of the general condition of the dam with respect to safety, based upon available data and visual inspection, in order to determine if the dam poses hazards to human life or property.

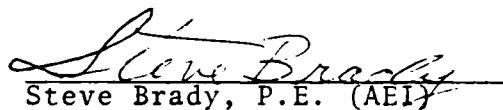
The guidelines used in the assessment were furnished by the Department of the Army, Office of the Chief of Engineers, and they have been developed with the help of several Federal and State agencies, professional engineering organizations, and private engineers. Based on these guidelines, the St. Louis District, Corps of Engineers has determined that this dam is in the high hazard potential classification, which means that loss of life and appreciable property loss could occur if the dam fails. The estimated damage zone extends approximately 3 miles downstream of the dam. Located within this zone are a 29 acre lake (MO I.D. 30268) and three dwellings. The dam is in the small size classification, since it is greater than 25 ft high but less than 40 ft high, and the maximum storage capacity is greater than 50 ac-ft but less than 1000 ac-ft.

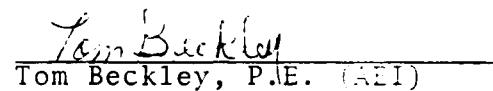
Our inspection and evaluation indicates that the combined spillways do not meet the criteria set forth in the guidelines for a dam having the above size and hazard potential. The combined spillways will pass 25 percent of the Probable Maximum Flood without overtopping. The Probable Maximum Flood is defined as the flood discharge that may be expected from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in the region. The guidelines require that a dam of small size with a high downstream hazard potential pass 50 to 100 percent of the PMF. Considering the small size of the dam and the low storage capacity, 50 percent of the PMF has been determined to be the appropriate spillway design flood. The 100-year frequency flood will not overtop the

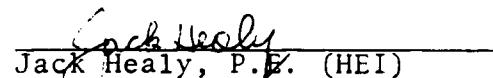
dam. The 100-year flood is one that has a 1 percent chance of being equaled or exceeded in any given year.

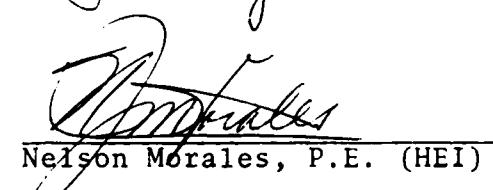
Deficiencies visually observed by the inspection team were: (1) seepage area on downstream face between Stations 3+10 and 3+40 about 10 ft below the crest; (2) apparent leakage of primary spillway pipe; (3) some brush and tree growth on the lower half of the downstream embankment face; (4) lack of wave protection for the upstream face of the dam; and (5) minor erosion on the downstream face at the north abutment-dam contact. Another deficiency was the lack of seepage and stability analysis records.

It is recommended that the owners take the necessary action in the near future to correct the deficiencies reported herein. A detailed discussion of these deficiencies is included in the following report.

  
Steve Brady, P.E. (AEI)

  
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AERIAL VIEW OF LAKE AND DAM

PHASE I INSPECTION REPORT  
NATIONAL DAM SAFETY PROGRAM  
ARROWHEAD LAKES LOWER DAM - ID No. 30267

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## SECTION 1 - PROJECT INFORMATION

### 1.1 GENERAL:

#### A. Authority:

The National Dam Inspection Act, Public Law 92-367, authorized the Secretary of the Army, through the Corps of Engineers, to initiate a program of safety inspection of dams throughout the United States. Pursuant to the above, the St. Louis District, Corps of Engineers, District Engineer directed that a safety inspection be made of Arrowhead Lakes Lower Dam in Dent County, Missouri.

#### B. Purpose of Inspection:

The purpose of the inspection was to make an assessment of the general condition of the dam with respect to safety, based upon available data and a visual inspection in order to determine if the dam poses hazards to human life or property.

#### C. Evaluation Criteria:

Criteria used to evaluate the dam were furnished by the Department of the Army, Office of the Chief of Engineers, "Recommended Guidelines for Safety Inspection of Dams, Appendix D." These guidelines were developed with the help of several federal agencies and many state agencies, professional engineering organizations, and private engineers.

### 1.2 DESCRIPTION OF PROJECT:

#### A. Description of Dam and Appurtenances:

Arrowhead Lakes Lower Dam is an earth fill structure approximately 27 ft high and 375 ft long at the crest. The appurtenant works consist of a 21 in. diameter corrugated metal primary spillway pipe with a 36 in. diameter riser, an earth swale emergency spillway and an 8 in. diameter steel drawdown pipe and gate valve. Sheet 3 of Appendix A shows a plan, profile and typical section of the embankment.

#### B. Location:

The dam is located in the north central part of Dent County, Missouri on a tributary of Meramec River. The dam

and lake are within the Salem, Missouri 15 minute quadrangle sheets (Section 5, T34N, R5W - latitude  $37^{\circ} 41.9'$ ; longitude  $91^{\circ} 30.2'$ ). Sheet 2 of Appendix A shows the general vicinity.

C. Size Classification:

With an embankment height of 27 ft and a maximum storage capacity of approximately 141 acre-ft, the dam is in the small size category.

D. Hazard Classification:

The St. Louis District, Corps of Engineers has classified this dam as a high hazard dam. The estimated damage zone extends approximately 3 miles downstream of the dam. Located within this zone are a 29 acre lake (MO I.D. 30268) and three dwellings.

E. Ownership:

The dam is owned by Mr. Vance Harper. The owner's address is Sligo Star Route, Salem, Missouri 65560 (telephone: 314-729-4014).

F. Purpose of Dam:

The dam was constructed primarily for a lakeside residential development, although some flood protection is also provided.

G. Design and Construction History:

No design information is available. Mr. David Warner, the builder and original owner, indicated that the Soil Conservation Service provided design and construction assistance for the dam. However, the SCS office in Salem, Missouri did not have any records in their files. Mr. Warner indicated that material for construction of the dam was obtained from the north abutment area. Mr. Warner also reported that a key trench about 20 ft deep and 12 ft wide with 1.0H:1.0V side slopes was provided for the dam. No internal drainage or zoning was apparently provided in the dam. The present owner bought the dam in 1976. No problems of seepage through the dam are reported to have occurred. The only reported post-construction change was the recent repair of erosion at the emergency spillway inlet area.

#### H. Normal Operating Procedures:

The normal flows are discharged through uncontrolled spillways. An 8 in. diameter steel pipe can be used to dewater the lake. Information from the owner indicates that the dam has never been overtopped. The emergency spillway has never been used, and the primary spillway has only operated once or twice each year.

#### 1.3 PERTINENT DATA:

Pertinent data about the dam, appurtenant works, and reservoir are presented in the following paragraphs. Sheet 3 of Appendix A presents a plan, profile and typical section of the embankment.

##### A. Drainage Area:

The drainage area for this dam, as obtained from the U.S.G.S. quad sheet, is approximately 275 acres.

##### B. Discharge at Dam Site:

- (1) All discharge at the dam site is through uncontrolled spillways.
- (2) Estimated Total Spillway Capacity at Maximum Pool (Top of Dam - El. 1164.2): 826 cfs
- (3) Estimated Capacity of Primary Spillway: 36 cfs
- (4) Estimated Experienced Maximum Flood at Dam Site: 34 cfs (Elev. 1161.3)
- (5) Diversion Tunnel Low Pool Outlet at Pool Elevation: Not Applicable
- (6) Diversion Tunnel Outlet at Pool Elevation: Not Applicable
- (7) Gated Spillway Capacity at Pool Elevation: Not Applicable
- (8) Gated Spillway Capacity at Maximum Pool Elevation: Not Applicable

C. Elevations:

All elevations are consistent with an assumed mean sea level elevation of 1159.2 for the crest of the primary spillway riser pipe (estimated from quadrangle map).

- (1) Top of Dam: 1164.2 (Low Point); 1164.9 (High Point)
- (2) Principal Spillway Crest: 1159.2
- (3) Emergency Spillway Crest: 1161.7
- (4) Principal Outlet Pipe Invert: 1138.0
- (5) Streambed at Centerline of Dam: 1137.7
- (6) Pool on Date of Inspection: 1158.9
- (7) Apparent High Water Mark: 1161.3
- (8) Maximum Tailwater: Unknown
- (9) Upstream Portal Invert Diversion Tunnel: Not Applicable
- (10) Downstream Portal Invert Diversion Tunnel: Not Applicable

D. Reservoir Lengths:

- (1) At Top of Dam: 1475 ft
- (2) At Principal Spillway Crest: 1050 ft
- (3) At Emergency Spillway Crest: 1250 ft

E. Storage Capacities:

- (1) At Principal Spillway Crest: 79 ac-ft
- (2) At Top of Dam: 141 ac-ft
- (3) At Emergency Spillway Crest: 110 ac-ft

F. Reservoir Surface Areas:

- (1) At Principal Spillway Crest: 11 ac.
- (2) At Top of Dam: 14 ac.
- (3) At Emergency Spillway Crest: 12.5 ac.

G. Dam:

- (1) Type: Earth
- (2) Length at Crest: 375 ft
- (3) Height: 27 ft
- (4) Top Width: 10 ft
- (5) Side Slopes: Upstream Irregular; Downstream Irregular  
(see Sheet 3, Appendix A)
- (6) Zoning: Apparently Homogeneous
- (7) Impervious Core: None
- (8) Cutoff: Key trench (12 ft wide, 20 ft deep - information from Mr. Warner)
- (9) Grout Curtain: Unknown

H. Diversion and Regulating Tunnel:

- (1) Type: Not Applicable
- (2) Length: Not Applicable
- (3) Closure: Not Applicable
- (4) Access: Not Applicable
- (5) Regulating Facilities: Not Applicable

I. Spillway:

I.1 Principal Spillway:

- (1) Location: South End of Dam (Station 0+70)
- (2) Type: Drop Inlet Pipe

I.2 Emergency Spillway:

- (1) Location: South Abutment
- (2) Type: Earth Cut

J. Regulating Outlets:

The only regulating outlet for this dam is an 8 in. diameter steel pipe that can be used for the drawdown of the lake. The pipe passes through the embankment at Station 1+20, and a gate valve is located at the downstream end of the pipe.

## SECTION 2 - ENGINEERING DATA

### 2.1 DESIGN:

Although Mr. Warner indicated that the Soil Conservation Service provided design and construction assistance, no design computations or reports for Arrowhead Lakes Lower Dam are available. No documentations of construction inspection records have been obtained. To our knowledge, there are no documented maintenance data.

#### A. Surveys:

No information regarding pre-construction surveys was able to be obtained. Sheet 3 of Appendix A presents a plan, profile and cross section of the dam from survey data obtained from the site inspection. The crest of the 36 in. diameter primary spillway riser pipe was used as a reference point to determine the other elevations. This reference point corresponds to an approximate M.S.L. elevation of 1159.2 as derived from a U.S.G.S. quadrangle map and our survey notes.

#### B. Geology and Subsurface Materials:

The site is located in the central portion of the Ozarks geologic region of Missouri. The Ozarks are characterized topographically by hills, plateaus and deep valleys. The most common bedrock types are dolomite, sandstone and chert. The "Geologic Map of Missouri" indicates that the bedrock in the site area consists primarily of the Gasconade formation of the Canadian Series in the Ordovician System. The Gasconade formation is predominantly a light brownish-gray, cherty dolomite. In the central Ozarks region, the average thickness of the Gasconade is 300 ft. Caves and springs are common in this formation.

The publication "Caves of Missouri" indicates that nine known caves exist in Dent County. Of the four caves within 10 miles of the site, three are clustered about 4 miles northeast of the site, and the fourth cave is about 4 miles southeast of the site.

The "Geologic Map of Missouri" indicates a normal fault passing about 11 miles northwest of the site in an east-west direction. The Missouri Geological Survey has indicated that the faults in this area are generally considered to be inactive and have been for several hundred million years.

The soils in the area of the dam are of the Nixa-Clarksville-Lebanon-Hobson soil association. These soils have developed from cherty dolomite, limestone and sandstone. The thickness of loessial deposits in upland areas may range from 2.5 ft to 5.0 ft. The published "Soil Survey of Dent County" indicates that the soils adjacent to the reservoir are the Coulstone and Clarksville cherty soils. These soils consist of a yellowish-red very cherty silty clay loam.

C. Foundation and Embankment Design:

No foundation and embankment design information was available. Seepage and stability analyses apparently were not performed as required in the guidelines. There is apparently no particular zoning of the embankment, and no internal drainage features are known to exist. No construction inspection test results have been obtained.

D. Hydrology and Hydraulics:

No hydrologic or hydraulic design computations for this dam were available. Based on a field check of spillway dimensions and embankment elevations, and a check of the drainage area on U.S.G.S. quad sheets, hydrologic analyses using U.S. Army Corps of Engineers guidelines were performed and appear in Appendix C, Sheets 1 to 8.

E. Structure:

No design information for the primary spillway or drawdown pipe was available.

2.2 CONSTRUCTION:

No construction inspection data were obtained.

2.3 OPERATION:

Normal flows are discharged through uncontrolled spillways. The only regulating facility associated with this dam is the 8 in. diameter steel pipe used for the drawdown of the lake. The brush and small tree growth on the lower half of the downstream face indicates that the dam has not been recently maintained.

2.4 EVALUATION:

A. Availability:

No engineering data, seepage or stability analyses, or construction test data were available.

B. Adequacy:

The engineering data available were inadequate to make a detailed assessment of the design, construction, and operation of this structure. Seepage and stability analyses comparable to the requirements of the "Recommended Guidelines for Safety Inspection of Dams" were not available, which is considered a deficiency. These seepage and stability analyses should be performed for appropriate loading conditions (including earthquake loads) and made a matter of record.

C. Validity:

To our knowledge, no valid engineering data on the design or construction of the embankment are available.

## SECTION 3 - VISUAL INSPECTION

### 3.1 FINDINGS:

#### A. General:

The field inspection was made on August 15, 1979. The inspection team consisted of personnel from Anderson Engineering, Inc. of Springfield, Missouri and Hanson Engineers, Inc. of Springfield, Illinois. The team members were:

John Healy - Hanson Engineers, Inc. (Geotechnical Engineer)  
Steve Brady - Anderson Engineering, Inc. (Civil Engineer)  
Tom Beckley - Anderson Engineering, Inc. (Civil Engineer)  
Nelson Morales - Hanson Engineers, Inc. (Hydraulic Engineer)  
Dan Kerns - Hanson Engineers, Inc. (Geotechnical Engineer)

Photographs of the dam, appurtenant structures, and the reservoir are presented in Appendix D.

#### B. Dam:

The dam appears to be generally in good condition. Minor erosion was observed on the downstream face at the north abutment-dam contact. No wave protection is provided for the upstream face of the dam, although no erosion or sloughing was observed. A seepage area was observed on the downstream face of the dam between Stations 3+10 and 3+40 about 10 ft below the crest. This seepage area was soft and wet, and no noticeable flow was observed. Some brush and small tree growth was noted on the lower half of the downstream embankment face. The primary spillway pipe was discharging about .5 gallons of water per minute, despite the reservoir being about .3 ft below the spillway crest. The primary spillway pipe appeared to be in good condition. However, the flow from the outlet would indicate that the pipe is leaking water. The owner indicated that the flow from the outlet stops when the reservoir level is a few feet below normal pool.

The horizontal and vertical alignments of the crest appeared good, and no surface cracking or unusual movement was obvious. Shallow auger probes into the embankment indicated the dam to consist of a brownish red silty clay with rock fragments. Information from Mr. Warner indicates that material for construction of the dam was obtained from the abutment areas.

C. Appurtenant Structures:

C.1 Primary Spillway:

The area around the intake to the primary spillway was clear. The trash rack appears to be in good condition. As previously discussed, the primary spillway pipe apparently leaks. A small plunge pool has eroded at the primary spillway outlet. The outlet channel is clear for about 200 ft before entering a wooded area.

C.2 Emergency Spillway:

The earth cut emergency spillway appears to be in good condition. The approach area to the emergency spillway was clear. Some erosion was observed at the emergency spillway entrance where drainage from the south abutment enters the lake. The owner has reported that this erosion area was filled with rock subsequent to our inspection. The emergency spillway outlet cascades down the south abutment and into the valley. No erosion or debris was noted in this area.

C.3 Drawdown Pipe:

The 8 in. diameter steel drawdown pipe and valve appeared to be in good condition (see Photo 13). It is not known whether the valve is operated periodically.

D. Reservoir:

The watershed is generally wooded and grass-covered with no agricultural activity. The slopes adjacent to the reservoir are moderate, and no sloughing or serious erosion was noted.

E. Downstream Channel:

The downstream channel is generally clear with some weed growth. The channel enters a wooded area about 200 ft downstream of the embankment toe.

3.2 EVALUATION:

Trees and brush on the dam constitute a potential seepage hazard and encourage animal burrowing. The seepage from the embankment face may adversely affect the stability of the dam. The apparent leakage from the primary spillway

pipe could worsen and either lower the normal pool of the lake or adversely affect the stability of the dam. These deficiencies should be corrected under the direction of an engineer experienced in the design and construction of dams.

Because the lake drain valve is located on the downstream side of the dam, the full head of water impounded by the dam is acting entirely through the dam. The area around the lake drain outlet should be periodically inspected for seepage which might indicate a leak or rupture of the drain pipe and could eventually initiate a piping failure through the embankment.

## SECTION 4 - OPERATIONAL PROCEDURES

### 4.1 PROCEDURES:

Although there is a drawdown pipe under this dam, no regulating procedures are known to exist. The pool is normally controlled by rainfall, runoff, evaporation, the capacities of the uncontrolled spillways, and the seepage from the reservoir.

### 4.2 MAINTENANCE OF DAM:

The presence of some small trees on the downstream face of the embankment indicates that the dam has not been maintained recently.

### 4.3 MAINTENANCE OF OPERATING FACILITIES:

The drawdown pipe and valve appeared to be in good condition. No regular maintenance program for the dewatering facility is known to exist.

### 4.4 DESCRIPTION OF ANY WARNING SYSTEM IN EFFECT:

The inspection team is unaware of any existing warning system for this dam.

### 4.5 EVALUATION:

The brush and trees on the lower embankment face, the seepage area on the downstream face of the dam, apparently leakage of the primary spillway pipe, and minor erosion at the north abutment-dam contact are serious deficiencies which should be corrected. However, to avoid creating an unsafe condition, these deficiencies should only be corrected under the direction of an engineer experienced in the design and construction of dams.

## SECTION 5 - HYDRAULIC/HYDROLOGIC

### 5.1 EVALUATION OF FEATURES:

#### A. & B. Design and Experience Data:

No hydrologic or hydraulic design computations for this dam were available.

The hydraulic and hydrologic analyses were based on: (1) a field survey of spillway dimensions and embankment elevations; and (2) an estimate of the pool and drainage areas from the U.S.G.S. quad sheet. The owner indicated that the dam has never overtopped, and the emergency spillway has never operated. The primary spillway has operated only once or twice each year. Our hydrologic and hydraulic analyses using U. S. Army Corps of Engineers guidelines appear in Appendix C.

#### C. Visual Observations:

The approach channels to the spillways are clear. There is apparently a leak (.5 gpm) in the primary spillway pipe. The outlet channel is fairly clear of brush and debris. The emergency spillway is well separated from the embankment, and spillway releases would not be expected to endanger the dam.

#### D. Overtopping Potential:

Based on the hydrologic and hydraulic analysis presented in Appendix C, the combined spillways will pass 25 percent of the Probable Maximum Flood. The Probable Maximum Flood is defined as the flood discharge that may be expected from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in the region. The recommended guidelines from the Department of the Army, Office of the Chief of Engineers, require that this structure (small size with high downstream hazard potential) pass 50 percent to 100 percent of the PMF, without overtopping. Considering the small size of the dam and the low storage capacity of the reservoir, 50 percent of the PMF has been determined to be the appropriate spillway design flood. The structure will pass a 100-year frequency flood without overtopping.

The routing of 50 percent of the PMF through the spillways and dam indicates that the dam will be overtopped by 0.97 ft at elevation 1165.17. The duration of the overtopping will be 1.17 hours, and the maximum outflow will be 2534 cfs. The maximum discharge capacity of the spillways is 826 cfs. Overtopping of an earthen embankment could cause serious erosion and could possibly lead to failure of the structure.

## SECTION 6 - STRUCTURAL STABILITY

### 6.1 EVALUATION OF STRUCTURAL STABILITY:

#### A. Visual Observations:

Observed features which could adversely affect the structural stability of this dam are discussed in Sections 3.1B and 3.2.

#### B. Design and Construction Data:

No design and construction data for the foundation and embankment were available. Seepage and stability analyses comparable to the requirements of the guidelines were not available, which constitutes a deficiency which should be rectified.

#### C. Operating Records:

No operating records have been obtained.

#### D. Post-Construction Changes:

The only reported post-construction change was the repairing of minor erosion at the entrance to the emergency spillway.

#### E. Seismic Stability:

The structure is located in seismic zone 1. An earthquake of this magnitude would not generally be expected to cause severe structural damage to a well constructed earth dam of this size. However, it is recommended that the prescribed seismic loading for this zone be applied in stability analyses performed for this dam.

## SECTION 7 - ASSESSMENT/REMEDIAL MEASURES

### 7.1 DAM ASSESSMENT:

This Phase I inspection and evaluation should not be considered as being comprehensive since the scope of work contracted for is far less detailed than would be required for an in-depth evaluation of dams. Latent deficiencies, which might be detected by a totally comprehensive investigation, could exist.

#### A. Safety:

The embankment is generally in good condition. Several items were noted during the visual inspection which should be investigated further, corrected or controlled. These items are: (1) seepage area on downstream face between Stations 3+10 and 3+40 about 10 ft below the crest; (2) apparent leakage of primary spillway pipe; (3) some brush and tree growth on the lower half of the downstream embankment face; (4) lack of wave protection for the upstream face of the dam; and (5) minor erosion on the downstream face at the north abutment-dam contact.

Another deficiency was the lack of seepage and stability analysis records.

The dam will be overtopped by flows in excess of 25 percent of the Probable Maximum Flood. Overtopping of an earthen embankment could cause serious erosion and could possibly lead to failure of the structure.

#### B. Adequacy of Information:

The conclusions in this report were based on the performance history as related by others, and visual observation of external conditions. The inspection team considers that these data are sufficient to support the conclusions herein. Seepage and stability analyses comparable to the "Recommended Guidelines for Safety Inspection of Dams" were not available, which is considered a deficiency.

#### C. Urgency:

The remedial measures recommended in paragraph 7.2 should be accomplished in the near future. If the deficiencies listed in paragraph A are not corrected, and if good maintenance is not provided, the embankment condition will

deteriorate and possibly could become serious in the future. The item recommended in paragraph 7.2A should be pursued promptly.

D. Necessity for Phase II:

Based on the result of the Phase I inspection, no Phase II inspection is recommended.

E. Seismic Stability:

The structure is located in seismic zone 1. An earthquake of this magnitude would not generally be expected to cause severe structural damage to a well constructed earth dam of this size. However, it is recommended that the prescribed seismic loading for this zone be applied in any stability analyses performed for this dam.

7.2 REMEDIAL MEASURES:

The following remedial measures and maintenance procedures are recommended. All remedial measures should be performed under the guidance of a professional engineer experienced in the design and construction of dams.

A. Alternatives:

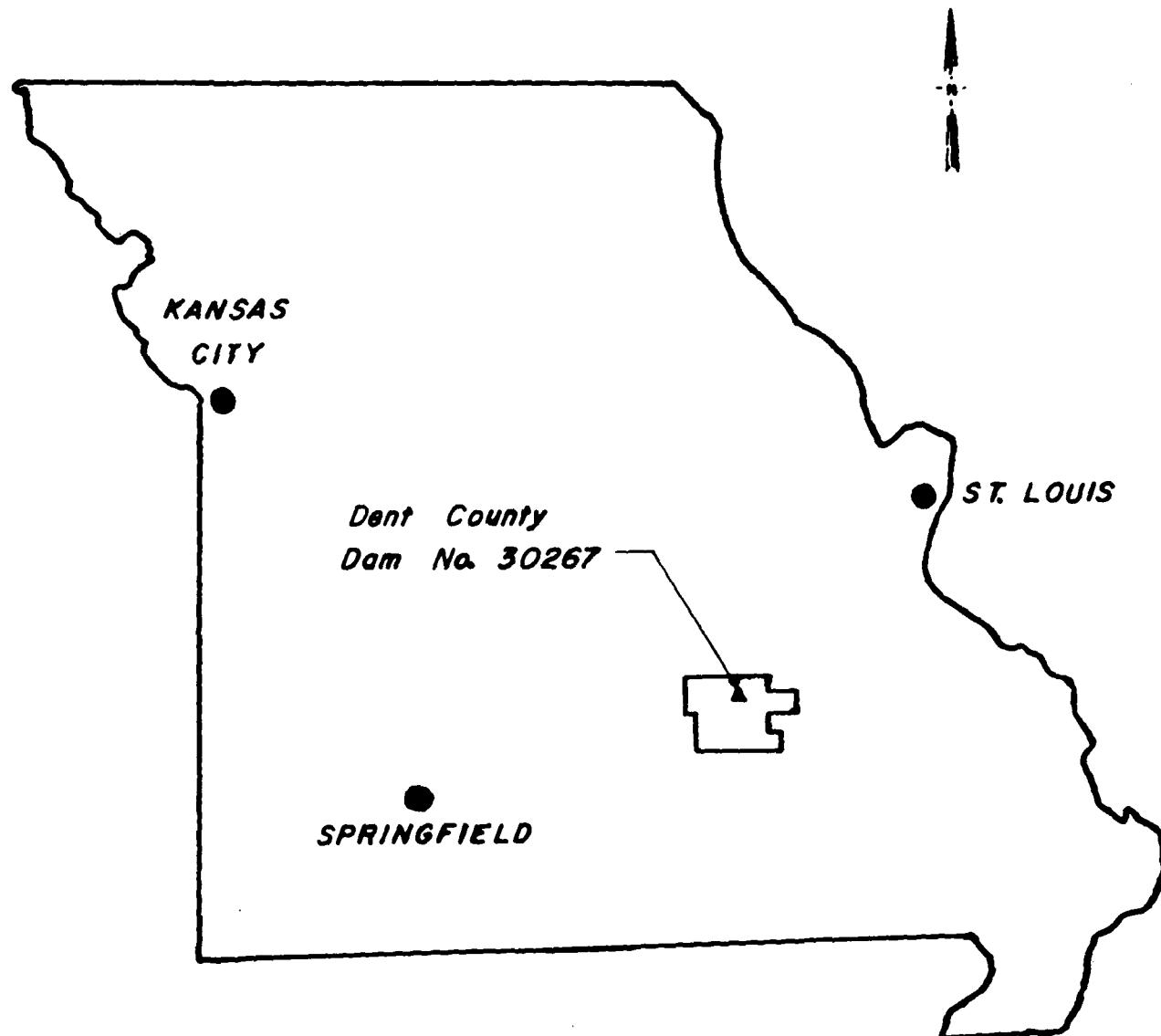
- (1) Spillway size and/or height of dam should be increased to pass 50 percent of the PMF. In either case, the spillway should be protected to prevent erosion.

B. O&M Procedures:

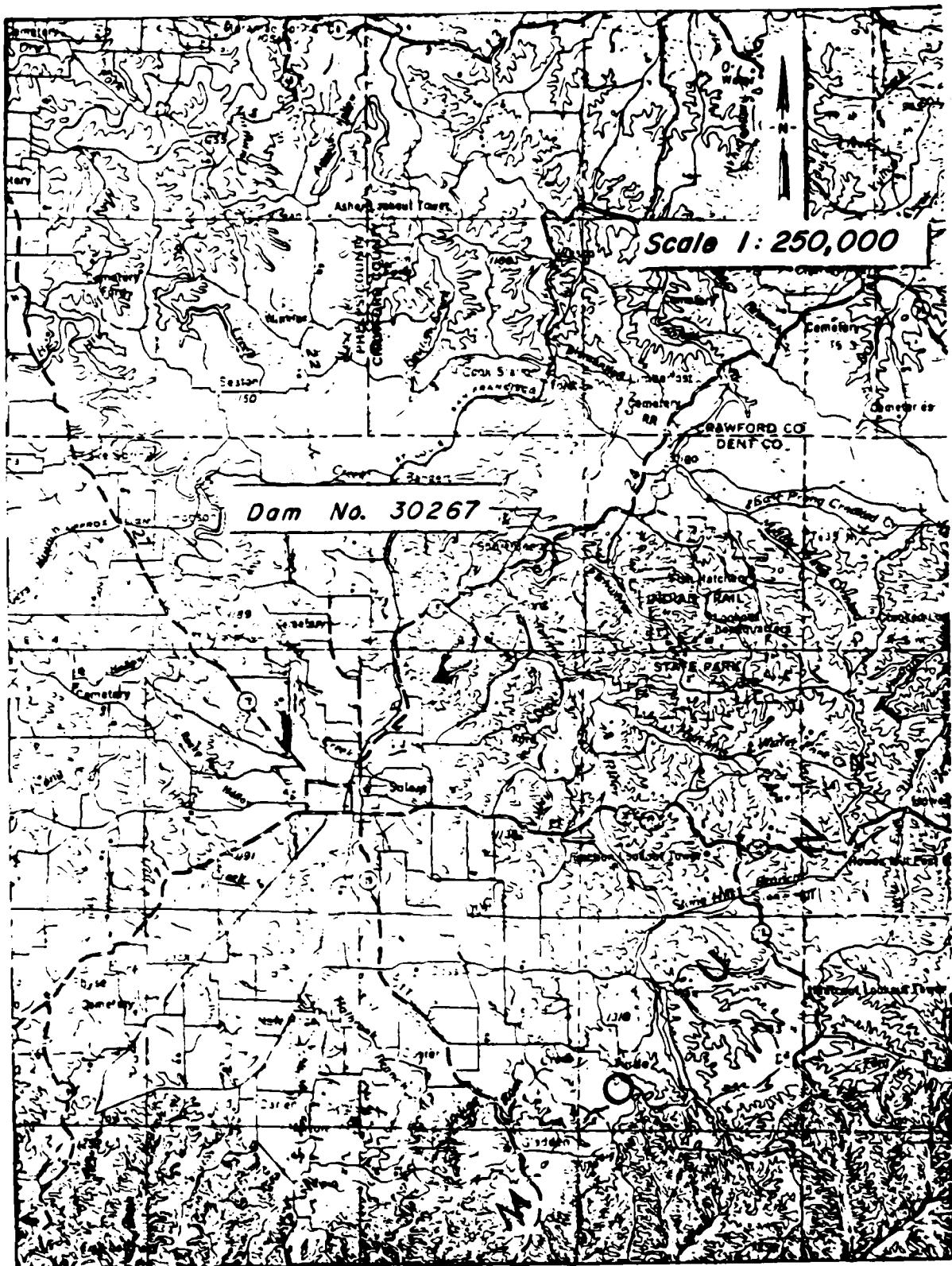
- (1) Seepage and stability analyses comparable to the requirements of the recommended guidelines should be performed by an engineer experienced in the construction of dams.
- (2) The seepage area on the downstream face of the dam between Stations 3+10 and 3+40 should be investigated by an engineer experienced in the design and construction of dams. Remedial measures may be required. As a minimum, this area should be drained and monitored to determine if there is any increase in quantities and whether soil particles are being carried with the water.

- (3) The trees, brush and weeds should be removed from the embankment face. The vegetative growth should be cut on an annual basis.
- (4) The leakage from the primary spillway pipe should be investigated and corrected.
- (5) Wave protection should be provided for the upstream face of the dam.
- (6) The minor erosion on the downstream embankment face at the north abutment-dam contact should be monitored and repaired if it becomes worse.
- (7) A detailed inspection of the dam should be made periodically by an engineer experienced in the design and construction of dams.

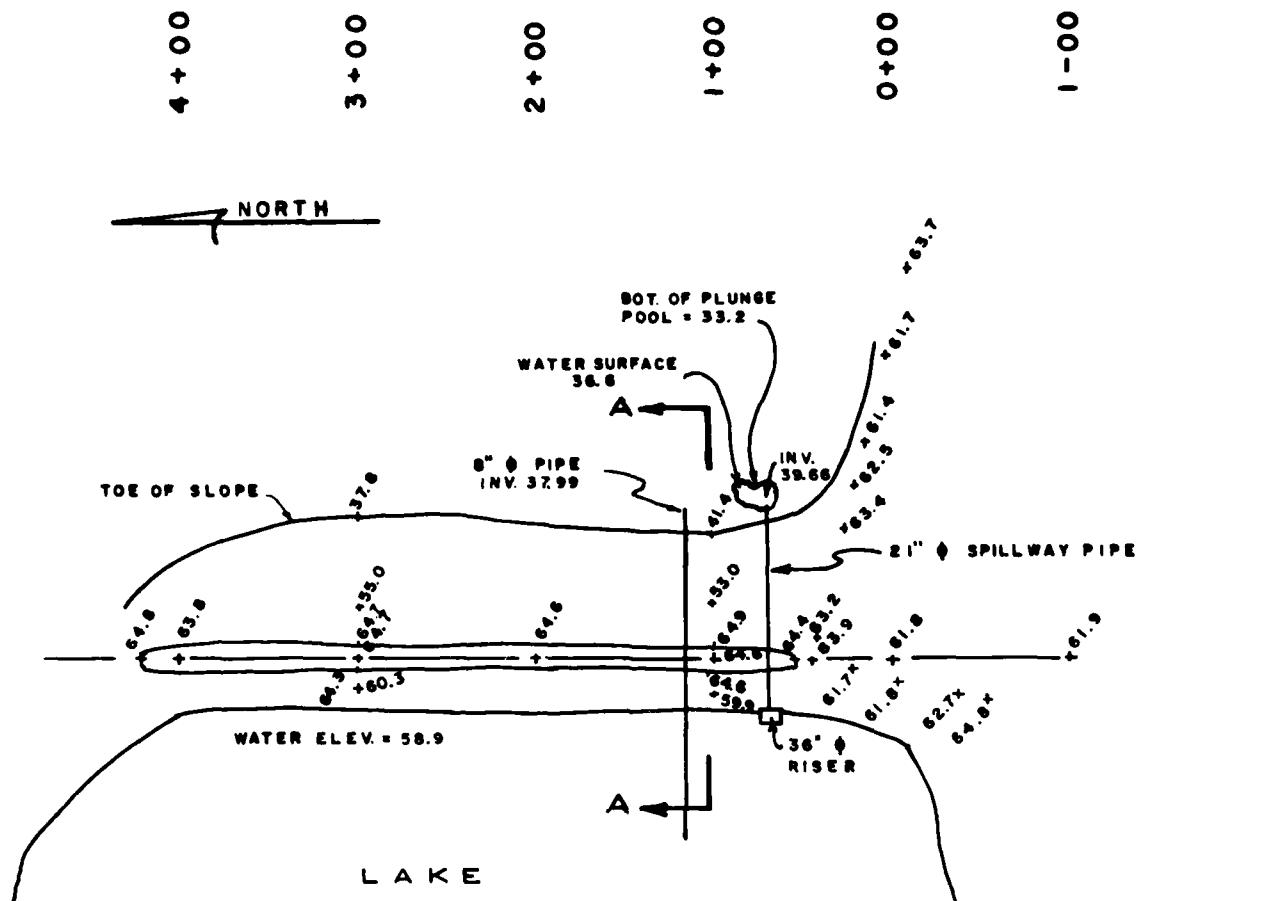
## **APPENDIX A**



LOCATION MAP



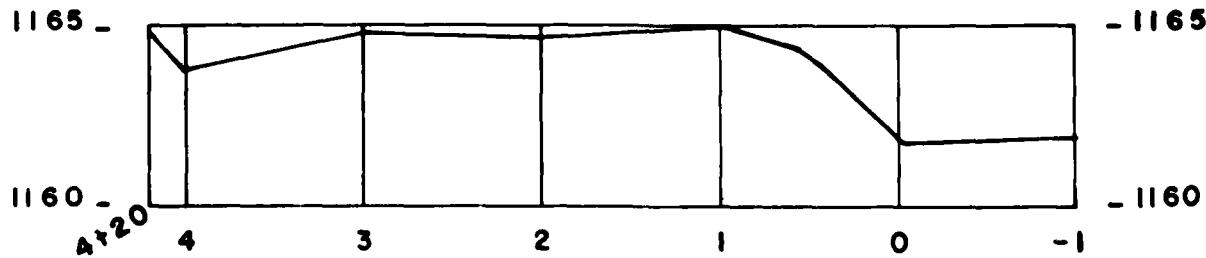
Sheet 2 Appendix A



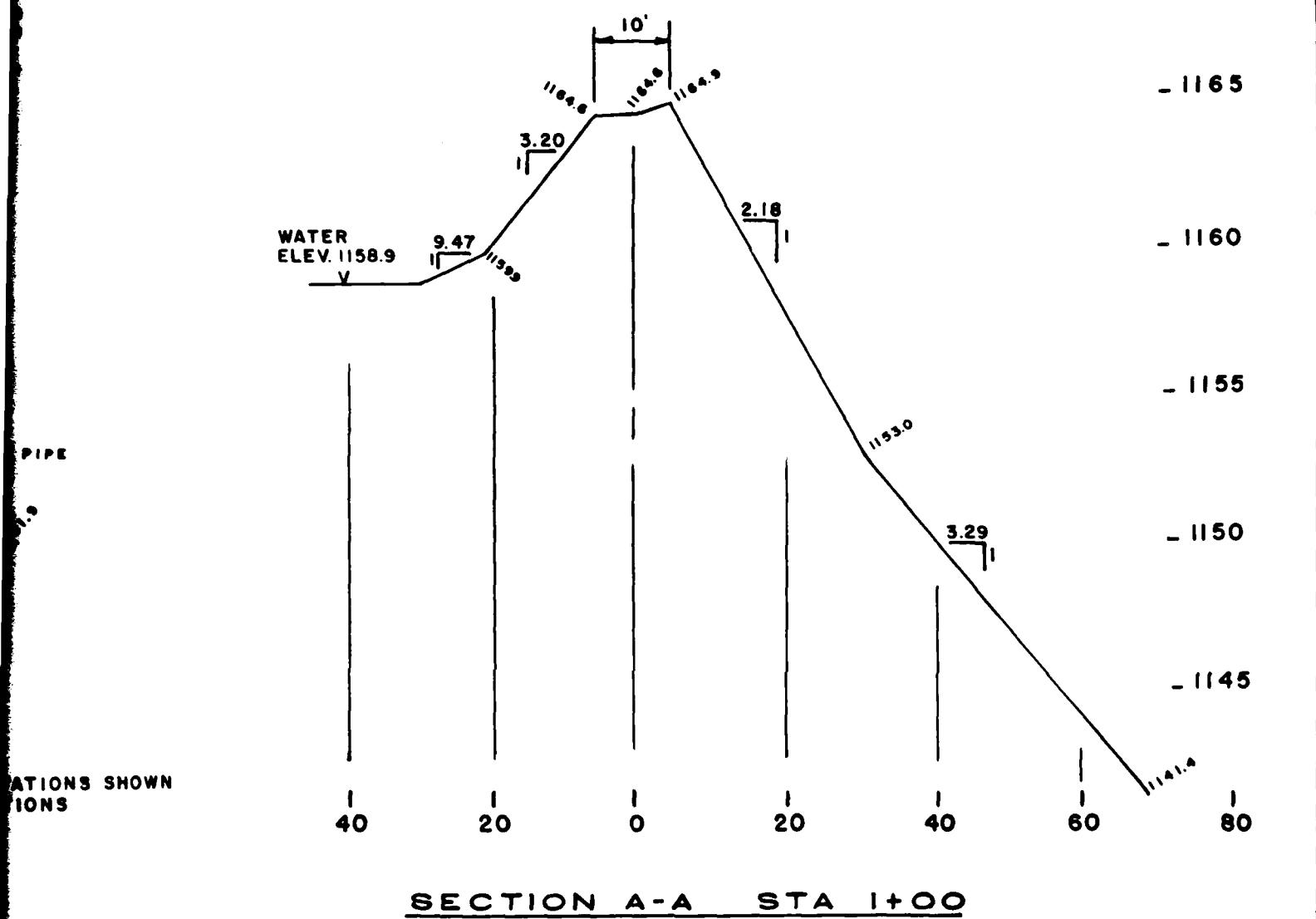
BENCHMARK:  
 TOP OF 36" Ø RISER  
 STA 0+70 ELEV = 1159.2 MSL

PLAN VIEW

SCALE: 1" = 100'



PROFILE



SHEET 3 OF APPENDIX A

ANDERSON ENGINEERING, INC.  
730 NORTH BENTON AVENUE  
SPRINGFIELD, MISSOURI 65802

ARROWHEAD LAKES

MO. No. 30267

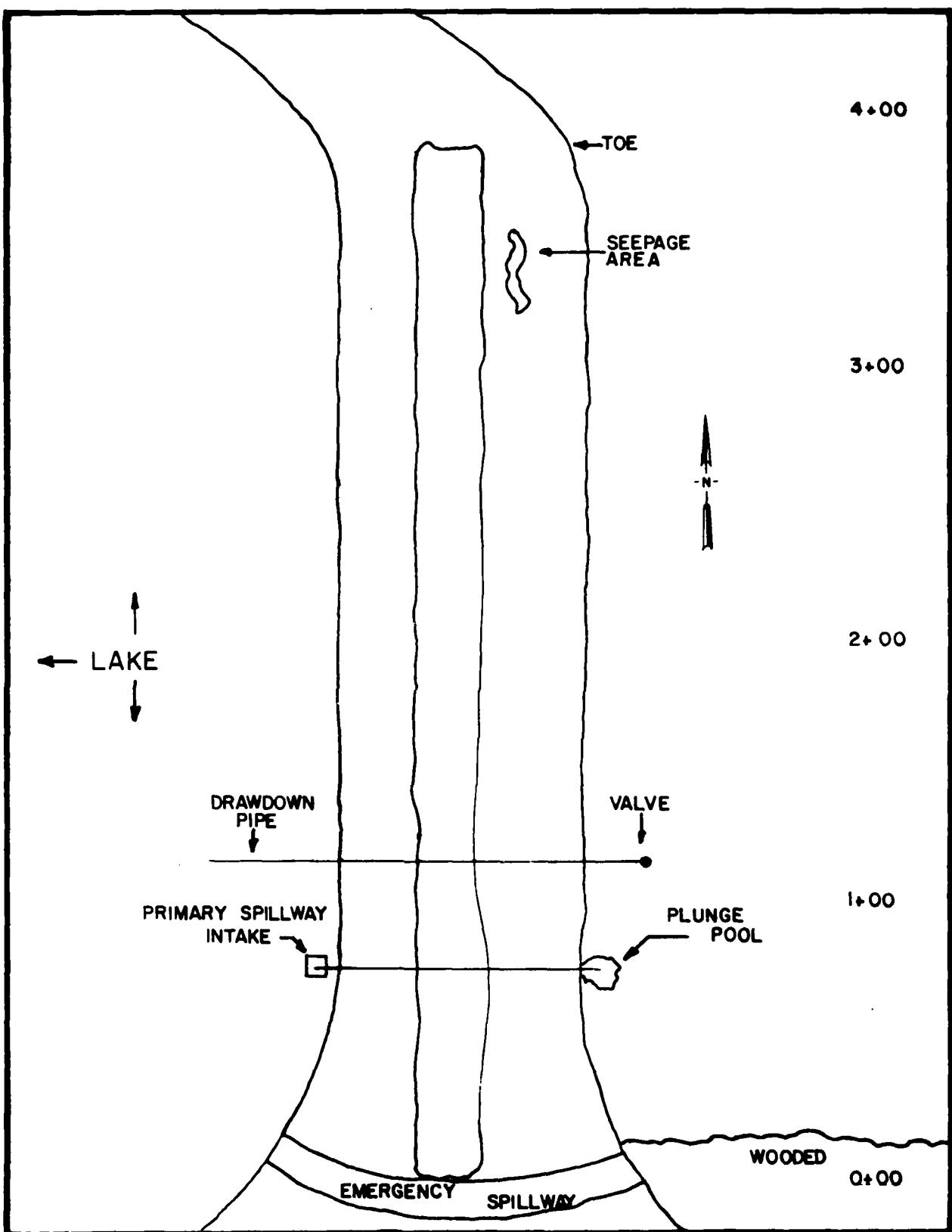
PLAN & PROFILE

DENT COUNTY, MO.

2

-1165

-1160



PLAN SKETCH

ARROWHEAD LAKES LOWER DAM

MO. I.D. 30267



SPRINGFIELD ILL.

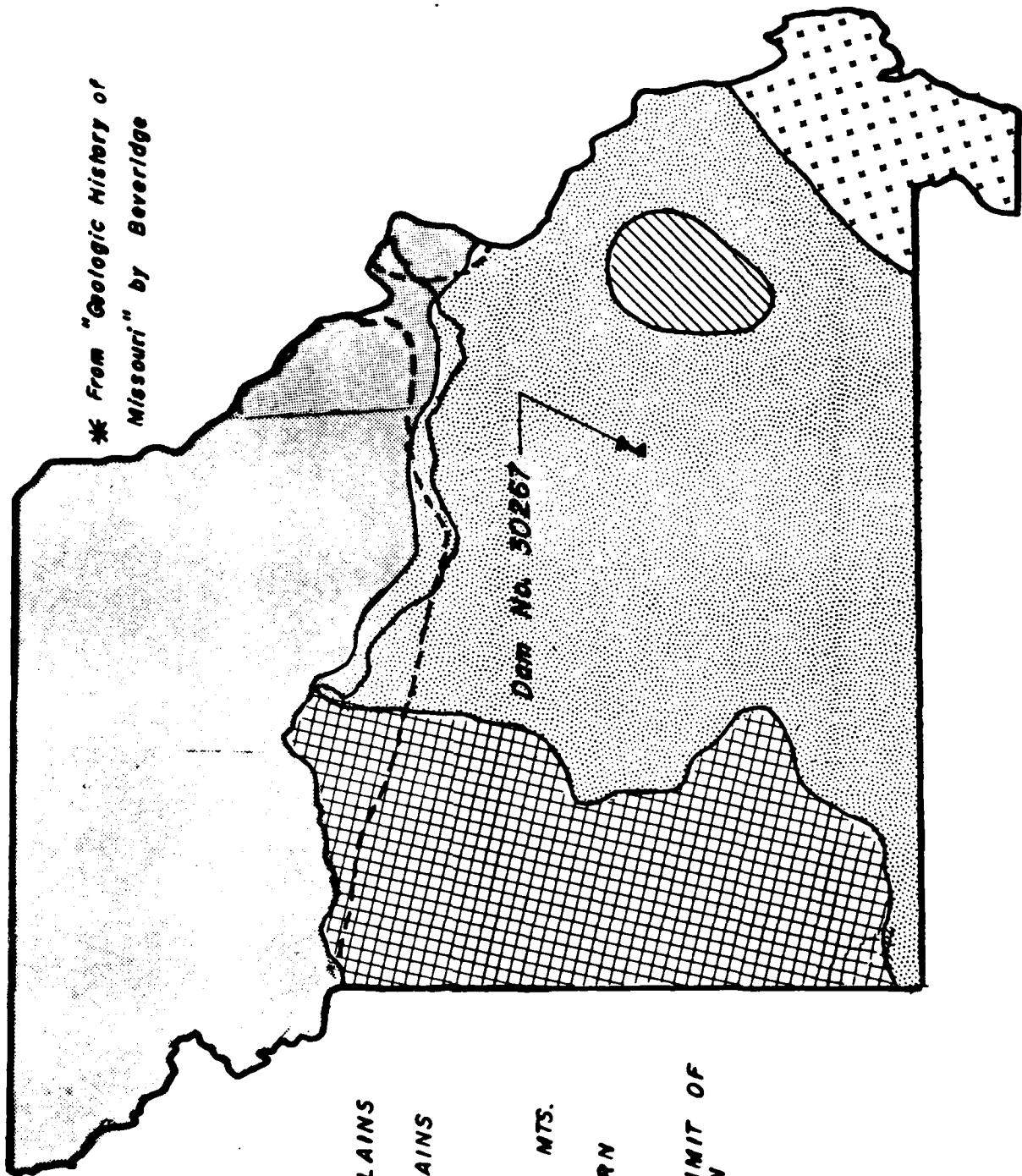
PEORIA ILL.

SHEET 4 APPENDIX A

## ***APPENDIX B***

MAJOR GEOLOGIC REGIONS OF MISSOURI

\* From "Geologic History of  
Missouri" by Beverage



GLACIATED PLAINS

WESTERN PLAINS

OZARKS

ST. FRANCOIS MTS.

SOUTHEASTERN

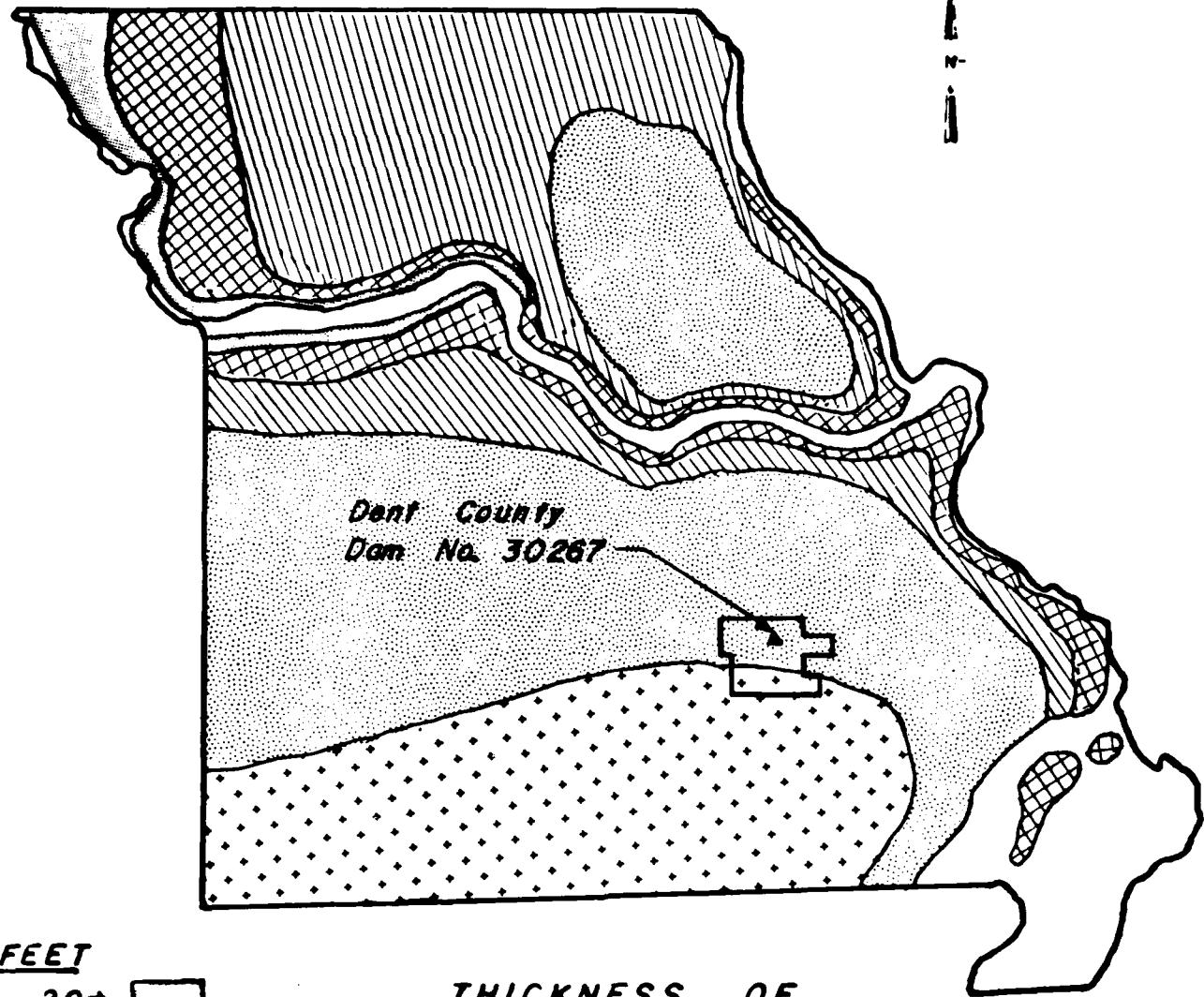
LOWLANDS

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SOUTHERN LIMIT OF

GLACIATION

\* From "Soils of Missouri"



FEET

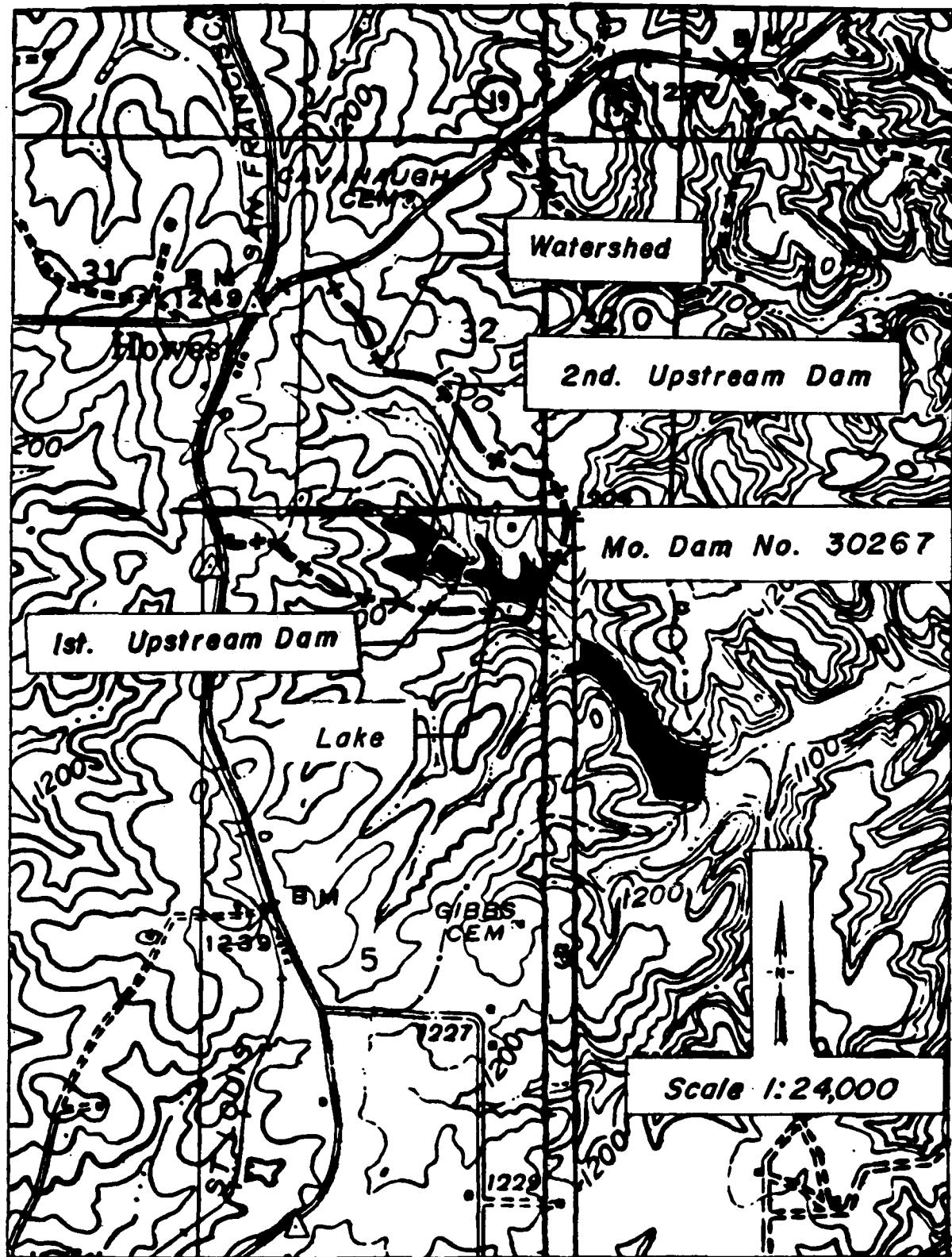
20+	[empty box]	<u>THICKNESS OF</u>
10 - 20	[grid pattern box]	<u>LOESSIAL DEPOSITS</u>
5 - 10	[vertical lines box]	
2.5 - 5	[dots box]	
2.5 -	[horizontal lines box]	

SHEET 2 OF APPENDIX B

## **APPENDIX C**

*From Salem 15' Quad*

*From Stone Hill 15' Quad*



## Lake and Watershed Map

## HYDRAULIC AND HYDROLOGIC DATA

Design Data: No design data are available.

Experience Data: No records are available. The owner indicated that the dam has never overtopped, and the emergency spillway has never operated. The primary spillway has operated only once or twice each year.

Visual Inspection: At the time of the inspection, the pool level was approximately 0.26 ft below normal pool.

Unit Hydrograph: Flood routings were performed to determine the overtopping potential. The watershed area was obtained by planimeter from the U.S.G.S., Salem, MO, 1.5 minute quadrangle map and the reservoir surface area from the U.S.G.S. Salem, Missouri 7.5 minute orthophotograph (advance print). The storage volume was developed from these data. A 5 minute interval unit hydrograph was developed for this watershed, which resulted in a peak inflow of 749 c.f.s. and a time to peak of 17 minutes. Application of the probable maximum precipitation minus losses results in a flood hydrograph peak inflow of 5703 c.f.s. Rainfall distribution for the 24 hour storm was according to EM 1110-2-1411.

The existence of two more dams upstream will reduce the effect of the design flood by storing part of the flood and by retarding the peak. To obtain a more realistic result of the flood routing studies, the PMF was considered acting simultaneously over the entire watershed area of the three dams. First, the PMF was routed through the reservoir and spillway of the 2nd upstream dam (see LAKE AND WATERSHED

MAP, sheet 1 Appendix C), then the outflow hydrograph from this dam was combined with the inflow hydrograph of the 1st upstream dam watershed and routed through the reservoir and spillway of the 1st upstream dam; finally, the outflow hydrograph from this dam combined with the inflow hydrograph from the watershed of the dam under consideration was routed through the reservoir and spillways of the last dam. The flood routing studies were made using the HEC-1 Dam Safety Version Program. The computer input, output and hydrograph for 50 percent of the PMF are presented on Sheets 6, 7 and 8 of Appendix C.

Sheet 3 Appendix C

OVERTOPPING ANALYSIS FOR ARROWHEAD LAKES LOWER DAM

INPUT PARAMETERS

1. Unit Hydrograph - SCS Dimensionless - Flood Hydrograph Package (HEC-1); Dam Safety Version Was Used.  
Hydraulic Inputs Are As Follows:
  - a. Twenty-four Hour Rainfall of 26.4 Inches For 200 Square Miles - All Season Envelope
  - b. Drainage Area = 275 Acres; = 0.43 Sq. Miles
  - c. Travel Time of Runoff 0.39 Hrs.; Lag Time 0.24 Hrs.
  - d. Soil Conservation Service Soil Group C
  - e. Soil Conservation Service Runoff Curve No. 85 (AMC III)  
70 AMC II
  - f. Proportion of Drainage Basin Impervious 0.04
2. Spillways
  - a. Primary Spillway: 36 in. I.D. CMP Riser and 21 in. I.D. CMP Outlet Pipe; Crest Elevation 1159.2
  - b. Emergency Spillway: Trapezoidal Cut Length 25 Ft.; Side Slopes Vary; C = Varies
  - c. Dam Overflow Length 375 Ft.; Crest El. 1164.2; C = 3.0
3. Spillway and Dam Rating:

Curve Prepared by Hanson Engineers. Data Provided To Computer on Y4 and Y5 Cards.

Formula Used: Primary Spillway: Chart for CMP Flowing Full

$$\text{Emergency Spillway: } \frac{Q^2}{g} = \frac{A^3}{T}$$

Note: Time of Concentration From Equation  $T_c = \frac{(11.9 L)^3}{H} .385$   
California Culvert Practice, California Highways and Public Works, Sept. 1942.

SUMMARY OF DAM SAFETY ANALYSIS

1. Unit Hydrograph
  - a. Peak - 749 c.f.s.
  - b. Time to Peak 17 Min.
2. Flood Routings Were Computed by the Modified Puls Method
  - a. Peak Inflow  
50% PMF 2699 c.f.s.; 100% PMF 5703 c.f.s.
  - b. Peak Elevation  
50% PMF 1165.17 100% PMF 1166.18
  - c. Portion of PMF That Will Reach Top of Dam  
25 %; Top of Dam Elev. 1164.2 Ft.
3. Computer Input and Output Data are shown on Sheets 5 and 6 of this Appendix.



## K1 RESERVOIR ROUTING BY MODIFIED PULS AT 1ST UPSTREAM DAM

	Y1	Y	1	1	1	1	-1
Y1	1						
Y41174.9	1174	1176	1177	1178	1179	1180	1181
Y5	0	400	1161	2276	3654	5320	7310
SA	0	3.7	5.6	6.4			
SE1159.2	1159.2	1173.1	1178	1180			
SS1174.9	1174.9						
SD	1178	3.0	1.5	270			
K	0	5			3	1	

K1 INFLOW HYDROGRAPH COMPUTATION FOR U. HARPER DAM (#14)

	N	1	2	0.43	0.43	1	1
--	---	---	---	------	------	---	---

	P	0	26.4	102	120	130	
--	---	---	------	-----	-----	-----	--

	T	U2	0.39	0.24			-85
--	---	----	------	------	--	--	-----

	X	0	-1	2			
--	---	---	----	---	--	--	--

	K	2	5		3	1	
--	---	---	---	--	---	---	--

K1 COMBINE ROUTED AND LOCAL INFLOW AT U. HARPER DAM (#14)

	K	1	6	0	4	1	
--	---	---	---	---	---	---	--

K1 RESERVOIR ROUTING BY MODIFIED PULS AT U. HARPER DAM (#14)

	Y1	1	1	1	1	1	
Y41159.2	1160	1161	1161.7	1163	1164.2	1165	1166
Y5	0	33	34	35	270	826	1316
SA	0	11	14	23			
SE1137.7	1137.7	1159.2	1164.2	1180			
SS1159.2	1159.2						
SD1164.2	1164.2	3.0	1.5	375			
K	99						

**PEAK FLOW AND STORAGE (END OF PERIOD) SUMMARY FOR MULTIPLE PLAN-RATIO ECONOMIC COMPUTATIONS  
FLOWS IN CUBIC FEET PER SECOND (CUBIC METERS PER SECOND)  
AREA IN SQUARE MILES (SQUARE KILOMETERS)**

OPERATION	STATION	AREA	PLAN	RATIO 1 0.15	RATIO 2 0.20	RATIO 3 0.30	RATIO 4 0.40	RATIO 5 0.50	RATIO 6 0.75	RATIO 7 1.00	RATIOS APPLIED TO FLOWS	
											(	)
HYDROGRAPH AT	1	0.10 ( 0.26)	1	229. ( 6.47)	305. ( 8.63)	457. ( 12.95)	610. ( 17.26)	762. ( 21.58)	1143. ( 32.37)	1524. ( 43.16)		
ROUTED TO	2	0.10 ( 0.26)	1	67. ( 1.89)	106. ( 3.00)	197. ( 5.57)	301. ( 8.53)	399. ( 11.29)	610. ( 17.26)	1103. ( 31.24)		
HYDROGRAPH AT	3	0.02 ( 0.05)	1	58. ( 1.65)	78. ( 2.20)	117. ( 3.31)	156. ( 4.41)	195. ( 5.51)	292. ( 8.26)	389. ( 11.02)		
2 COMBINED	3	0.12 ( 0.31)	1	87. ( 2.48)	143. ( 4.06)	228. ( 6.45)	353. ( 10.00)	468. ( 13.26)	718. ( 20.32)	1242. ( 33.16)		
ROUTED TO	4	0.12 ( 0.31)	1	58. ( 1.64)	112. ( 3.16)	213. ( 6.03)	321. ( 9.10)	435. ( 12.31)	695. ( 19.69)	1107. ( 31.33)		
HYDROGRAPH AT	5	0.43 ( 1.11)	1	691. ( 19.57)	922. ( 26.09)	1382. ( 39.14)	1843. ( 52.19)	2304. ( 65.24)	3456. ( 97.85)	4608. ( 130.47)		
2 COMBINED	5	0.55 ( 1.42)	1	691. ( 19.57)	994. ( 28.15)	1576. ( 44.62)	2137. ( 60.50)	2699. ( 76.42)	4143. ( 117.32)	5703. ( 161.49)		
ROUTED TO	6	0.55 ( 1.42)	1	348. ( 9.86)	635. ( 17.98)	1308. ( 37.04)	1956. ( 55.39)	2534. ( 71.76)	3993. ( 113.06)	5576. ( 157.90)		

## SUMMARY OF DAM SAFETY ANALYSIS

PLAN	1	.....	ELEVATION	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
			STORAGE	1190.19	1191.60	1193.90
			OUTFLOW	43.	55.	80.
						622.

RATIO OF RESERVOIR P.M.F.	MAXIMUM DEPTH U.S.ELEV	MAXIMUM OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	MAX OUTFLOW HOURS	TIME OF FAILURE HOURS	TIME OF FAILURE HOURS
A-15	1192.00	0.00	67:	0.00	15.92	0.00		

## PLAN 1 .....

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	1190.19	1191.60	1193.90
STORAGE	43.	55.	80.
OUTFLOW	0.	0.	622.

RATIO OF RESERVOIR P.M.F.	MAXIMUM DEPTH U.S.ELEV	MAXIMUM STORAGE OVER DAM	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
0.15	1192.08	0.00	60.	67.	0.00	15.92
0.20	1192.36	0.00	63.	106.	0.00	15.92
0.30	1192.75	0.00	67.	197.	0.00	15.83
0.40	1193.04	0.00	70.	301.	0.00	15.83
0.50	1193.30	0.00	73.	399.	0.00	15.75
0.75	1193.87	0.00	79.	610.	0.00	15.75
1.00	1194.19	0.29	83.	1103.	0.33	15.75

## SUMMARY OF DAM SAFETY ANALYSIS

## PLAN 1 .....

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	1173.06	1174.90	1178.00
STORAGE	17.	24.	40.
OUTFLOW	0.	0.	2276.

RATIO OF RESERVOIR P.M.F.	MAXIMUM DEPTH U.S.ELEV	MAXIMUM STORAGE OVER DAM	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
0.15	1175.06	0.00	25.	58.	0.00	16.67
0.20	1175.21	0.00	26.	112.	0.00	16.08
0.30	1175.49	0.00	27.	213.	0.00	15.92
0.40	1175.78	0.00	28.	321.	0.00	15.92
0.50	1176.05	0.00	30.	435.	0.00	15.83
0.75	1176.39	0.00	31.	695.	0.00	15.83
1.00	1176.93	0.00	34.	1107.	0.00	15.83

## SUMMARY OF DAM SAFETY ANALYSIS

## PLAN 1 .....

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	1159.19	1159.20	1164.20
STORAGE	79.	79.	141.
OUTFLOW	0.	0.	826.

RATIO OF RESERVOIR P.M.F.	MAXIMUM DEPTH U.S.ELEV	MAXIMUM STORAGE OVER DAM	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
0.15	1163.17	0.00	127.	348.	0.00	16.08
0.20	1163.79	0.00	135.	635.	0.00	16.08
0.30	1164.57	0.37	146.	1308.	0.50	15.92
0.40	1164.92	0.72	151.	1956.	0.83	15.92
0.50	1165.17	0.97	155.	2534.	1.17	15.92
0.75	1165.72	1.52	163.	3993.	3.58	15.83
1.00	1166.18	1.98	170.	5576.	5.08	15.83

## DISCHARGE (C. F. S.)

2800

2400

2000

1600

1200

800

400

0

11.45141.0	1
11.50142.0	1
11.55143.0	1
12.00144.0	1
12.05145.0	1
12.10146.0	1
12.15147.0	1
12.20148.0	1
12.25149.0	1
12.30150.0	1
12.35151.0	1
12.40152.0	1
12.45153.0	1
12.50154.0	1
12.55155.0	1
13.00156.0	1
13.05157.0	1
13.10158.0	1
13.15159.0	1
13.20160.0	1
13.25161.0	1
13.30162.0	1
13.35163.0	1
13.40164.0	1
13.45165.0	1
13.50166.0	1
13.55167.0	1
14.00168.0	1
14.05169.0	1
14.10170.0	1
14.15171.0	1
14.20172.0	1
14.25173.0	1
14.30174.0	1
14.35175.0	1
14.40176.0	1
14.45177.0	1
14.50178.0	1
14.55179.0	1
15.00180.0	1
15.05181.0	1
15.10182.0	1
15.15183.0	1
15.20184.0	1
15.25185.0	1
15.30186.0	1
15.35187.0	1
15.40188.0	1
15.45189.0	1

INFLOW - OUTFLOW

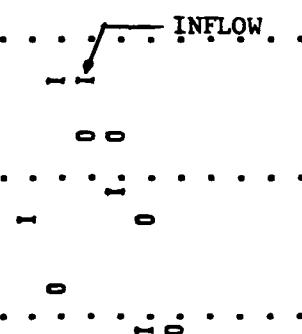
HYDROGRAPH

FOR 50% P.M.F.

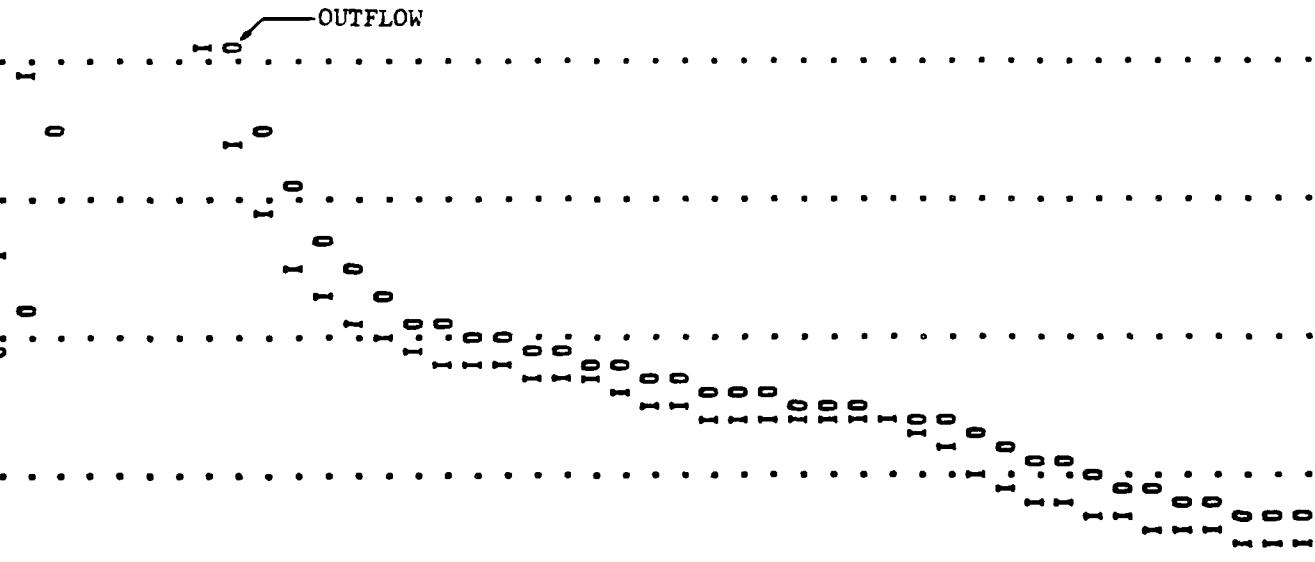
MAX. INFLOW = 2699 C. F. S.

MAX. OUTFLOW = 2534 C. F. S.

INFLOW



OUTFLOW

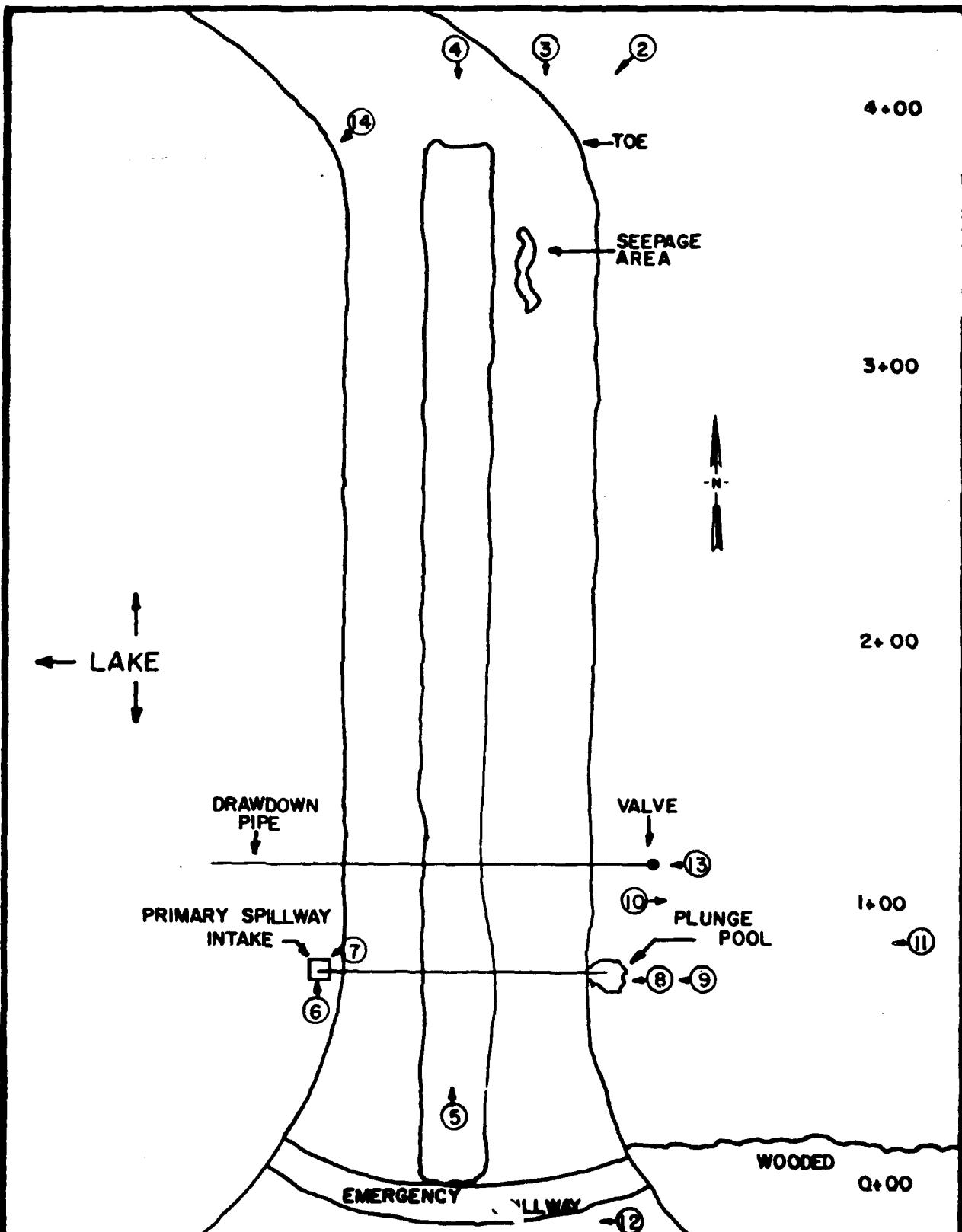


TIME (hrs.)

## ***APPENDIX D***

## INDEX TO PHOTOGRAPHS

<u>Photo No.</u>	<u>Description</u>
1	Aerial - Arrowhead Lakes (Lower Dam in Left Center of Picture; Mo. I.D. 30268 in Background)
2	Overview of Dam, Looking Southwest
3	Downstream Face of Dam, Looking South
4	Crest of Dam, Looking South
5	Crest of Dam, Looking North
6	Primary Spillway Inlet Structure
7	Close-Up of Primary Spillway Inlet
8	Primary Spillway Outlet Pipe
9	Primary Spillway Outlet and Plunge Pool
10	Downstream Channel, Looking Downstream
11	Downstream Channel, Looking Upstream
12	Emergency Spillway, Looking Upstream
13	Drawdown Pipe Valve and Outlet
14	View of Lake and Watershed
15	Arrowhead Lakes Middle Dam, Looking North
16	Arrowhead Lakes Upper Dam, Looking Northeast







10

12

8

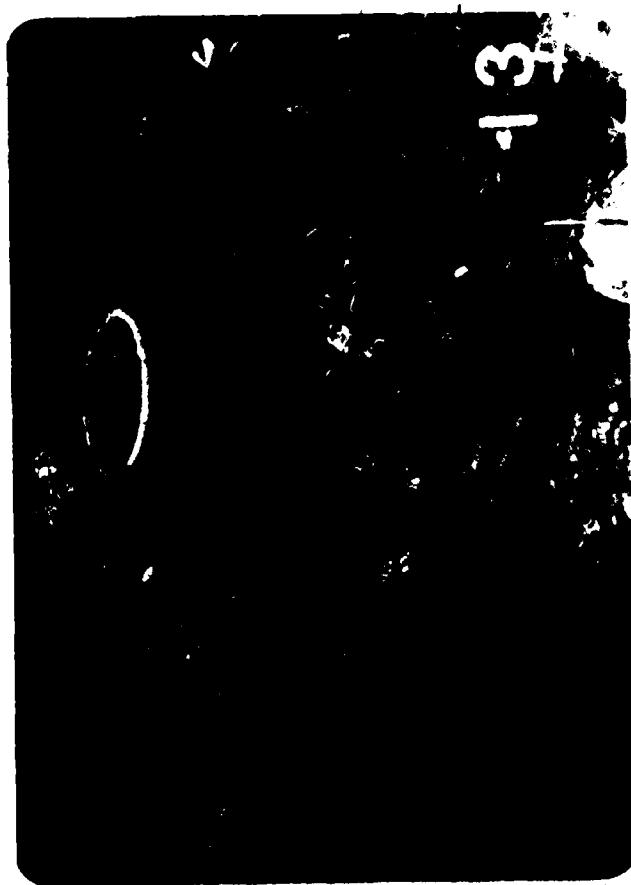
16



15



13



**DAU  
ILM**